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Market structure, fragmentation, and market quality ☆

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Abstract

This paper studies the impact of order flow fragmentation on market quality. Due to differences in market structure, order flow becomes more consolidated when stocks switch listings from a dealer market (NASDAQ) to an exchange (NYSE). We find that the post-switch improvements of market quality are related to the degree of order flow fragmentation on NASDAQ as well as the change of fragmentation after trading on the NYSE. After controlling and correcting for potential selection bias arising from a nonrandom sample, we find that order flow fragmentation affects market quality as predicted by finance theories. Our paper shows that order flow consolidation is particularly valuable for less liquid securities.

JEL classification: G23; G24

Keywords: Market fragmentation; Market quality; Best execution

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0. Introduction

A key issue of interest to financial economists is why the same or similar securities have different trading characteristics in differently structured markets. This issue has raised questions about optimal market design. One of the goals of market design is to facilitate liquidity provision and price efficiency. Order handling rules, decimal pricing and new trading technology have narrowed the difference between the New York Stock Exchange (NYSE) and NASDAQ in terms of trading as well as market quality.[1] A key difference of trading, however, still exists between these two types of market structures. On a dealer market, such as NASDAQ, order flows are usually more fragmented than on an exchange, such as the NYSE, where all buy and sell orders are consolidated and interact with each other. Indeed, a significant amount of trading of NASDAQ-listed stocks takes place on various ECNs and dealers.[2] Many studies compare market quality across different market structures, but there is limited evidence explaining why observed differences exist in recent periods.[3] This paper utilizes natural experiments of exchange switching to examine the impact of order flow fragmentation on market quality.

Due to differences in market structure, NASDAQ stocks are traded by a large number of market venues, including NASDAQ SuperMontage, various ECNs, dealers, and regional exchanges, and therefore have a higher degree of order flow fragmentation than their NYSE peers. When NASDAQ stocks switch listing to the NYSE, order flows migrate from dealers and ECNs to the exchange and become more consolidated. Such natural experiments allow us to examine the impact of order flow fragmentation on liquidity provision and price efficiency. Using switching stocks in this study enables us to control for firm characteristics and remove potential influence due to an imperfect match.

Market fragmentation has been widely studied in the literature. Theoretical work of Mendelson (1987) and Madhavan (1995) shows that fragmentation can result in reduced liquidity, higher price volatility, and violations of price efficiency. Empirical evidence on fragmentation and market quality is, however, inconclusive. Some studies find negative effects of decentralized, or "fragmented," trading on market quality.[4] Others show that fragmentation with competition does not hurt market quality.[5] Amihud et al. (2003) provide evidence that order consolidation improves liquidity and pricing, and Barclay and Hendershott (2004) show the positive impact of trading consolidation on liquidity.

We examine the stocks of 39 companies that transferred from NASDAQ to the NYSE during 2002 and the first quarter of 2003. The stocks in our sample on average have a market capitalization of $1.4 billion each and trade 650,000 shares daily. They are not large and actively traded stocks if compared to index stocks and actively traded ETFs.[6] We

[1]See Weston (2000), Sapp and Yan (2003), and Boehmer (2005).

[2]During our sample period, about 80% of 11Ac1–5 eligible orders are executed by ECNs when the stocks are listed on NASDAQ. The ratio of 11Ac1–5 executed shares to twice of consolidated tape volume is about 40% during our sample period.

[3]See Lee (1993), Goldstein (1994), Christie and Huang (1994), Barclay (1997), Bessembinder and Kaufman (1997), Bessembinder (1999), Heidle and Huang (1999), Huang and Stoll (1999), Venkataraman (2000), Jones and Lipson (1999), Bessembinder (2003), among others.

[4]See Cohen et al. (1985), Porter and Thatcher (1998), and Cohen et al. (1982) among others.

[5]See Neal (1987), Battalio (1997), Fong et al (2001), Conrad et al. (2005), Mayhew (2003), Wahal (1997), among others.

[6]The average market capitalization for an S&P 500 stock is about $20 billion during our sample period. The average daily volume for the active ETFS (DIA, SPY, QQQQ) are between 10 and 150 million shares each.

find that, as in earlier studies, the stocks that switch to the NYSE experience improvement in liquidity provision and price efficiency. We observe reductions in quoted and effective spreads as well as volatility. We also find the realized spreads drop sharply and are negative on the NYSE, suggesting more competitive liquidity provision on the NYSE than NASDAQ. Regarding execution speed, we find that the NYSE is faster for market orders, but NASDAQ is faster overall.

Our study finds that market fragmentation explains the market quality changes. Using the SEC 11Ac1–5 execution data, we develop proxies to quantify order flow fragmentation. We find that the post-switch magnitude of market quality improvements is related to the degree of order flow fragmentation on NASDAQ as well as the change of fragmentation after trading on the NYSE. In addition, we find stock liquidity is negatively correlated with the post-switch reduction in volatility and execution cost, suggesting that the order flow consolidation is particularly valuable for less liquid securities.

Compared to pre-decimal and pre-NASDAQ reform periods, the evidence in this paper shows that the NASDAQ-NYSE differences in quoted and effective spreads become smaller. Liquidity provision on the NYSE and NASDAQ has been studied intensively in the literature with the conclusion that the NYSE provides lower execution costs and volatility than NASDAQ.[7] Recent evidence has shown that the NASDAQ's reform in 1997 has improved its market quality and narrows the spread difference between NASDAQ and the NYSE (Weston (2000) and Sapp and Yan (2003)). In Boehmer (2005), the magnitudes of differences of NYSE-NASDAQ matched samples are smaller than previously documented.[8] We believe the narrowing differences between NASDAQ and the NYSE relate to increased competition within NASDAQ (order handling rules), reduction of minimum price variation (decimalization), higher degree of market transparency (SEC 11Ac1–5 Rule), as well as improved inter-market linkages among NASDAQ market centers, which help to reduce market segmentation and increase inter-market competition.

Our finding suggests the incremental value of order flow consolidation on market quality above and beyond the aforementioned measures of improving competition, transparency, and market efficiency on NASDAQ. Furthermore, the average market quality differences that we have found in this paper, 3 cents (10 bp) on quoted spread and 3 cents (16 bp) in effective spread, are comparable to Boehmer (2005) and economically significant, particularly considering overall decreasing transaction cost and increasing trading volume.[9]

Our study supports the notion of a tradeoff in market structure between order flow consolidation and competition among market centers. There is evidence that the positive effect of competition may dominate in certain markets for intrinsically highly liquid

[7] See Christie and Huang (1994), Barclay (1997), Heidle and Huang (1999), and Bessembinder (1999), Kadlec and McConnell (1994), Jain and Kim (2003), Huang and Stoll (1996), LaPlante and Muscarella (1997), Keim and Madhavan (1996), Bessembinder and Kaufman (1997), Jones and Lipson (1999), Weaver (2002), SEC (2001), Boehmer (2008), Chung and Kim (2005), among others.

[8] Sapp and Yan (2003) report that the improvements on quoted spreads and effective spreads from NYSE listing are 2.95 cents (20 bp) and 7.4 cents (30 bp). Boehmer (2005) documents that the difference between NASDAQ and the NYSE is decreasing, from 6.5 cents (27 bp) in November 2001 to 3.7 cents (16 bp) in December 2002.

[9] GAO (2005) reports that quoted spreads range from 3 to 8 cents and effective spreads from 5 to 9 cents for 300 pairs of NYSE-NASDAQ stocks in post-decimalization period, and the daily trading volume has increased 80–100%, from 800 (1,071) million shares in 1999 to 1,500 (1,808) million shares in 2004 on the NYSE (NASDAQ).

securities.[10] The stocks we examine in this paper are not the most liquid and actively traded securities. Electronic order routing technology and automatic execution may have improved the inter-market competition, but it appears that competition among these market centers does not dominate the benefits of order flow consolidation for these securities. Our findings illustrate the positive impact of order flow consolidation on market quality and price efficiency.

Our paper finds that the extreme value volatility measurement complements the conventional return-variance volatility. Volatility measured by extreme value, such as high and low prices, is highly correlated with return-variance volatility and closely relates to market structure. Since our sample of switching stocks is not random and our study may involve a selection bias, we employ three different ways to address the possibility of sample selection bias, including a simple sample comparison, the use of a matched control sample, and the Heckman 2-stage selection model. We find our results are not affected by the sample selection bias.

Our paper proceeds as follows. Section 1 introduces our sample and data for the stocks that switched markets, and describes our methodology. Section 2 presents the findings on changes in volatility and information efficiency of prices for switching stocks. Section 3 presents the evidence on quoted and effective spreads. Section 4 examines and rejects the hypothesis of selection bias for the switching stocks. Section 5 gives additional evidence for fragmentation effects, making use of cross-sectional differences among switching stocks. Section 6 concludes.

1. Sample and data

Our sample consists of 39 U.S. companies that voluntarily switch their listings from NASDAQ to the NYSE during January 2002 to March 2003.[11] We focus on these relatively recently transferred stocks so that our results would reflect the effects of decimalization in addition to technological and market structure changes such as the growth of ECNs.[12]

The data that have been used in this study are from publicly available sources.[13] The sample statistics are summarized and reported in Table 1 for the 39 companies that have

[10]Boehmer and Boehmer (2003) find evidence that the introduction of the NYSE trading on the three most liquid ETFs (QQQ, SPY, and DIA) has improved market quality, and Hendershott and Jones (2003) show that Island ECN contributes to price discovery of the same three ETFs.

[11]No firms voluntarily switched from the NYSE to NASDAQ during this period. Several delisted NYSE firms, such as Kmart, subsequently traded on NASDAQ market, at low prices and liquidity.

[12]We identified 65 US domestic firms that have switched listings from NASDAQ to the NYSE since January 2001, the beginning of the decimalization period. We require each stock in our sample to have at least 3 months of order execution data before and after its switch. We obtained the order-level execution quality data from the monthly publications by each market center in compliance with the SEC Rule 11Ac1–5 (Dash5) rule. The order level execution data became available in the middle of 2001 for the NYSE listed stocks and in October 2001 for NASDAQ stocks. After the 3-month filter, our sample reduces from 65 to 39 companies with 36 companies transferred in 2002 and 3 transferred in 2003.

[13]Stock prices, trading volumes, numbers of trades, and trade sizes are from the TAQ database. Market capitalization, shares outstanding and other company-specific data are from the CRSP database. Effective spreads are from the market quality data reports by markets under SEC Rule 11Ac1–5 (Dash5). Following the September 11, 2001 terrorist attack on the World Trade Center, the SEC postponed the deadline for NASDAQ stocks to be included in the Dash5 reports, but most market centers nonetheless began reporting in October as originally scheduled.

Table 1
Sample descriptive statistics and comparison

We report firm characteristics for 39 transferred stocks and 660 NASDAQ NYSE-eligible firms that are eligible for the NYSE listing standards as of December 2001. For each variable, we report the mean, median, maximum, minimum, the 25th percentile, and the 75th percentile across sample firms. Except for Distance, all other variables are computed using the CRSP daily file during January 1, 2001 to December 31, 2001. Distance is measured between the New York City and the capital city of the US state in which the company headquarter is located as of December 31, 2001. SIC Industry Concentration Index by number of firm is computed as the ratio between the number of NASDAQ firms who are eligible for the NYSE listing standards in a particular SIC major group, to the total number of the NYSE firms and the NASDAQ NYSE-eligible firms in that SIC major group. SIC Industry Concentration Index by Market Cap is computed as the ratio between the total market cap of all Nasdaq NYSE-eligible firms to the total market cap of the NYSE firms and the NASDAQ NYSE-eligible firms in that SIC major group.

Variable description	Number of firms	Mean	Median	25%	75%	Max	Min
Panel A: the 39 transferred firms							
Market cap ($M)	39	1,379.82	687.28	339.62	1,507.32	12,328.38	92.64
Daily volume (shares)	39	671,126.30	273,180.09	116,898.30	545,231.41	7,000,596.13	4,735.41
Daily closing price (unit = $)	39	25.88	23.46	18.33	31.01	53.33	6.50
Daily high-low price range (%)	39	4.86	4.62	3.61	6.20	11.07	1.76
Share outstanding (million shares)	39	52.40	27.85	16.03	58.64	307.07	4.77
Daily close-to-close return (%)	39	0.25	0.16	0.05	0.38	1.18	−0.11
Daily closing spread ($0.01)	39	13.77	10.78	7.04	16.13	59.79	3.00
Relative daily close spread (%)	39	0.65	0.49	0.35	0.83	2.01	0.08
Registered market maker count	39	27.28	24.33	18.50	32.64	66.75	9.33
Daily return Std (%)	39	3.69	3.45	2.68	4.66	9.22	1.32
Distance (miles)	39	1,075.85	832.00	288.00	1,629.00	4,968.00	1.00
SIC index by firm number	39	0.34	0.32	0.19	0.55	0.63	0.05
SIC index by market cap	39	0.18	0.12	0.03	0.16	0.54	0.01
Panel B: 660 NASDAQ NYSE-eligible firms							
Market cap ($M)	660	3,512.89	764.29	370.17	1,813.06	335,834.13	54.68
Daily volume (shares)	660	1,846,647.01	279,545.39	85,779.40	947,381.12	85,869,764.06	3,627.12
Daily closing price (unit = $)	660	25.97	23.36	16.46	32.50	93.85	5.05
Daily high-low price range (%)	660	5.44	5.12	3.75	6.72	12.38	1.54
Share outstanding (million shares)	660	126.58	32.79	18.60	75.81	7,301.24	1.91
Daily close-to-close return (%)	660	0.11	0.11	0.01	0.20	3.58	−7.80
Daily closing spread ($0.01)	660	12.98	10.27	6.06	16.60	106.95	−2.29
Relative daily close spread (%)	660	0.61	0.50	0.26	0.84	3.13	−0.40
Registered market maker count	660	32.10	26.08	18.63	39.96	110.58	6.17
Daily return Std (%)	660	4.12	3.84	2.78	5.20	9.78	1.26
Distance (miles)	660	1,243.31	912.00	273.00	2,509.00	4,968.00	1.00
SIC index by firm number	660	0.42	0.42	0.25	0.55	1.00	0.00
SIC index by market cap	660	0.28	0.16	0.12	0.47	1.00	0.00

switched.[14] Table 1 also includes statistics for 660 NASDAQ-listed companies that appear to be eligible for the NYSE listing as of December 2001, including the 39 transferred. Appendix A presents more details about the 39 transferred stocks during the 60-day window prior to their switches. The sample of switching stocks has an average market capitalization of $1.4 billion and a median of $687 million. The daily volatility of the sample, measured by the standard deviation of close-to-close return, is between 3% and 4%. The average daily closing price for the sample stocks ranges from $10 to $58, with a mean of $24. Quoted spreads for our study are the National Best Bids and Offers (NBBO). We compile the NBBO quotes from the CQ (Consolidated Quotes) file in the TAQ (Trades And Quotes) database.[15]

Besides the above information, we also develop three variables for the 39 switching firms and the 660 NYSE-eligible NASDAQ companies. Distance, measured in miles, is the geographic distance between New York City and the capital city of the US state in which a company's headquarters are located as of December 2001. We use this variable later to test the hypothesis that physical distance affects companies' switching decisions. We also employ two variables to study industry concentration and examine whether the industry concentration on NASDAQ affects firms' listing choice. Industry Concentration Index by number of firms is defined as the ratio between the number of NASDAQ NYSE-eligible companies to the total number of NASDAQ NYSE-eligible firms and the NYSE firms in a particular SIC (Standard Industry Classification) major industry group. We also use market capitalization to replace the number of firms and obtain the second variable of industry concentration index by market capitalization. The statistical results show that the concentration index by number of firms is larger than the concentration index by market capitalization, suggesting that NASDAQ firms are smaller in terms of market capitalization than their NYSE industry peers. As shown in the lower panel of Table 1, the median market capitalization and other variables for the 660 NASDAQ firms that are eligible for the NYSE listing standards are generally similar to those for the 39 switchers, suggesting that the 39 switching companies do not have any special attributes described in Table 1.

Table 2 reports the market fragmentation on NASDAQ and the NYSE in panel A. We propose two measures as proxies of market fragmentation. One is the Herfindahl–Hirschman index (HHI), based on the distribution of the number of orders that are covered in the Dash5 reports across market centers. HHI is computed as the sum of the squared market share of covered orders of each market center reported in the dash 5 data. Table 2 shows that HHI increases from 0.44 to 0.97 in median value for the stocks switched. The evidence is consistent with the market structure of NASDAQ, an ECN-dealership market, versus the NYSE, a centralized auction market with about 80% market share in trading of its listed stocks. We also measure fragmentation simply as the number of market centers that trade for a stock. The average number of market centers that receive order flows and provide executions on NASDAQ is 22 per stock, with a maximum of 59

[14]We will treat the timing of switches as exogenous. Although one might hypothesize that switches are timed to increase their effect on market quality, the selection bias correction applied later in our study mitigates any such hypothetical effect. In any case, it is unlikely to be significant because the timing of switches is planned in advance and not well suited to capture short-term fluctuations in the relative trading conditions between the two markets, even if these were foreseeable.

[15]In compiling the NBBO quotes, we use all quotes from the NYSE, NASDAQ, and all regional stock exchanges.

market centers for the sample stocks in our paper. In comparison, the NYSE has 7 market centers on average.[16] The standard deviations of the two fragmentation measures are also higher on NASDAQ market, reflecting that NASDAQ has a larger variation in fragmentation across stocks.

Fig. 1 shows the order flow migration around the switch and fragmentation measure on NASDAQ and the NYSE. When stocks switch listings, order flow can migrate from NASDAQ and ECNs to the NYSE in search of liquidity. We cannot distinguish ECNs trading on the consolidated trade tape (CT).[17] We only obtain the aggregate volume of NASDAQ SuperMontage, ECNs and dealers and the aggregate volume of ECNs and regional exchanges. Fig. 1(A) demonstrates that the majority of volume on NASDAQ market is done by NASDAQ SuperMontage, ECNs, and dealers, and 80–85% of trading volume migrates to the NYSE after the switches. This migration is voluntary since NASDAQ, ECNs, and dealers can still trade NYSE listed stocks. The voluntary migration of order flow relates to the better execution quality on the NYSE. Fig. 1(B) shows the monthly average of HHI index across 39 stocks around the switches. The HHI index is between 0.4–0.5 on NASDAQ and 0.9–1.00 on the NYSE. The evidence strengthens the notion that NASDAQ trading is more fragmented than the NYSE.

Data on execution quality and measures of market fragmentation are from the data reported by market centers under the requirement of the SEC Rule 11Ac1–5 ("Dash5"). Panel B of Table 2 summarizes and reports the Dash5 data for the 39 sample stocks.[18] The SEC 11Ac1–5 statistics reveal that trading strategies are different for the NYSE and NASDAQ orders, the latter being more weighted toward marketable limit orders rather than market orders and having a higher cancellation rate.[19] We treat the cancellation rate and order distribution among order types as reflecting different strategies adapted for different market structures, rather than as market quality measures *per se*.

2. Volatility and price efficiency

In this section we examine volatility and price efficiency. We find that volatility, in particular short-term volatility, falls after stocks switch. Using several methods we find

[16]The SEC grants certain two exemptions from the 11Ac1–5 rule, one for very inactively traded securities and one for small market centers that do not focus their business on active trading of the securities. The SEC exempts any national market system security that did not average more than 5 reported transactions per trading day, as disseminated pursuant to an effective transaction reporting plan, for each of the preceding six months (or such shorter time that the security has been designated a national market system security). Second, the SEC is exempting any market center that reported fewer than 200 transactions per trading day on average over the preceding six-month period in securities that are covered by the Rule. For further information, please see SEC, 2001, "Exemptive Order: NASD Small Firm Advisory Board on Rule 11Ac1–5," June 22, 2001.

[17]On the Consolidated Trade tape, ECNs trades are reported under NASDAQ as well as regional stock exchanges.

[18]Rule 11Ac1–5 requires market centers to make available to the public monthly electronic reports that include uniform statistical measures of execution quality. For every security and month, each market center is required to report execution quality measures, including effective spreads, realized spreads, and execution speed, for various order types and sizes.

[19]Rule 11Ac1–5 executions, cancellations, and order data, when aggregated across reporting market centers, include double counting due to orders being received by a market that then routes the orders elsewhere for execution. Such practices occur considerably more for NASDAQ listed stocks, and the aggregated data must be interpreted with caution.

Table 2
Market fragmentation and the SEC 11Ac1–5 report summary

We report the monthly average descriptive statistics for the 11Ac1–5 data. Our sample includes the 39 stocks that have transferred their listings from NASDAQ to the NYSE during January 2002 to March 2003. Our Dash5 data includes market order and marketable limit order. We obtain separate results by order type (market orders and marketable limit orders) and by order size (size 21 = 100–499 shares, 22 = 500–1999 share; 23 = 2000–4999 shares; 24 = 5000–9999 shares). Executed percentage is the ratio of the executed share to the covered share; cancelled percentage is the ratio of the cancelled shares to the covered shares; executed away percentage is the ratio of the executed away shares to the executed shares. HHI (Herfindahl-Hirschman Index) is computed as the sum of the squared market share of covered orders of each market center reported in the 11Ac1–5. MCNUM is the number of market centers in the 11Ac1–5 data. The investigation window is (−3, −1) for NASDAQ and (+1, +3) for the NYSE, relative to the switching month of each stock. We exclude the month in which the stocks switched. Our sample period is from October 2001 to June 2003.

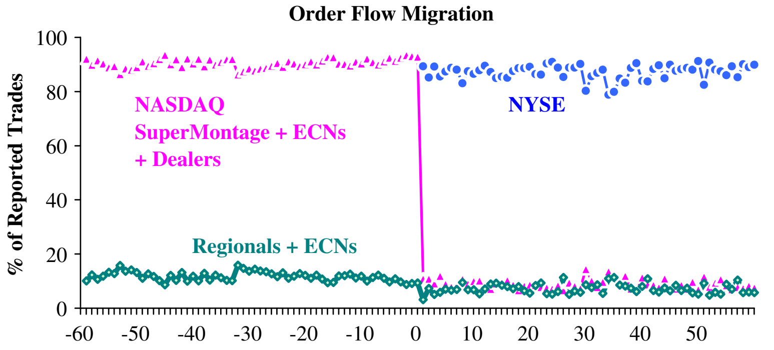
Panel A: market fragmentation

	Sample	NASDAQ					NYSE				
		Mean	Median	SD	Max	Min	Mean	Median	SD	Max	Min
HHI	39	0.47	0.44	0.12	0.70	0.29	0.95	0.97	0.06	0.99	0.68
MCNUM	39	22	20	10	58	6	7	6	3	16	3

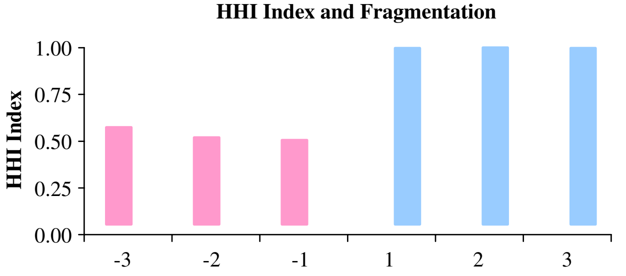
Panel B: shares covered, executed, and cancelled in Dash5

	Sample	Order type or size (shares)	Covered shares	Weight of covered shares	Executed shares	Weight of executed shares	Executed percentage	Cancelled shares	Cancelled (%)	Executed away shares	Executed away (%)
Overall											
NASDAQ	39	All	13,119,888	1.00	7,604,819	1.00	0.59	5,391,400	0.38	594,551	0.11
NYSE	39	All	5,283,117	1.00	4,677,901	1.00	0.88	571,196	0.11	41,766	0.01

by order type											
NASDAQ	39	Market	1,447,403	0.11	1,380,036	0.18	0.89	37,339	0.07	31,786	0.08
NASDAQ	39	M.Limit	11,672,491	0.89	6,224,788	0.82	0.55	5,354,061	0.42	562,770	0.12
NYSE	39	Market	2,361,153	0.45	2,319,427	0.50	0.98	30,797	0.01	30,863	0.02
NYSE	39	M.Limit	2,921,964	0.55	2,358,474	0.50	0.81	540,398	0.18	10,903	0.00
by order size											
NASDAQ	39	100–500	2,501,845	0.19	1,752,140	0.23	0.80	788,164	0.21	143,914	0.12
NASDAQ	39	500–1999	6,058,474	0.46	3,719,051	0.49	0.62	2,301,254	0.35	262,278	0.10
NASDAQ	39	2000–4999	2,623,095	0.20	1,346,739	0.18	0.49	1,223,206	0.46	108,340	0.11
NASDAQ	39	5000–9999	1,987,646	0.15	807,733	0.11	0.35	1,107,173	0.56	82,127	0.12
NYSE	39	100–500	1,173,371	0.22	1,066,680	0.23	0.92	104,667	0.08	5,192	0.01
NYSE	39	500–1999	2,195,508	0.42	1,965,077	0.42	0.89	220,111	0.10	18,778	0.01
NYSE	39	2000–4999	1,182,241	0.22	1,035,299	0.22	0.83	136,012	0.15	10,877	0.01
NYSE	39	5000–9999	731,998	0.14	610,845	0.13	0.77	110,406	0.20	6,919	0.01



(A)



(B)

Fig. 1. Order flow migration and fragmentation. (A) Shows the order flow migration from NASDAQ to the NYSE when stocks switch listings. We report the percentage of reported volume on the consolidated tape (CT). The investigation period is (−60, +59). (B) Presents the monthly average HHI (Herfindahl–Hirschman Index) across 39 stocks during (−3, −1) and (+1, +3) months around the switch. HHI is computed as the sum of the squared market share of covered orders of each market center reported in the 11Ac1–5. We compute the HHI for each stock in each month, and average them across stocks to obtain the monthly average. Our sample includes 39 stocks that have transferred their listings from NASDAQ to the NYSE during January 2002 to March 2003. Our investigation window is (−3, −1) and (+1, +3) months relative to each stock's transfer month. The sample period covers from October 2001 to June 2003.

that the volatility related to transitory price movements falls and the information efficiency of prices improves on the NYSE.

2.1. Reduction of volatility

Since daily volatilities reflect more market and company news, our preferred approach is to focus on volatility for shorter periods, such as 5-min intervals. Price movements during short intervals contain less fundamental news and are more reflective of transitory price changes due to market structure differences or order imbalances. We measure returns based on both trade prices and quote midpoints to control for bid-ask bounce. We also examine returns using open-to-open and close-to-close intervals. The various methods produce qualitatively similar results. Panel A of Table 3 reports 5-min returns measured using quote midpoints in close-to-close intervals.[20] The short-term return volatilities over

[20]We also replicate the study by examining bid-to-bid and ask-to-ask returns. The results are not materially different.

Table 3
Changes of volatility and price efficiency

We report 5-min return standard deviation, return autocorrelation, and Hasbrouck (1993) variance decomposition in Panel A, B, and C. We divide the daily trading regular hour (9:30AM–4:00PM) into 78 5-min intervals. We measure both daily close-to-close return as well as 5-min interval close-to-close return based on quote midpoint. Hasbrouck (1993) decomposes the variance of transaction prices into variance of efficient prices and variance due to pricing error. Our sample includes the 39 stocks that have transferred their listings from NASDAQ to the NYSE during January 2002 to March 2003. The tick-by-tick trade and quote data is from the TAQ database. We conduct the t tests for the mean difference and the Wilcoxon test for the median difference, and provide p values in parentheses. Our computation window is (−60, −1) for NASDAQ trading and (0, 59) for the NYSE trading relative to each stock's transfer date. Our sample period is from October 2001 to June 2003.

	Sample	NASDAQ (%)	NYSE (%)	NYSE–NASDAQ (%)
Panel A: 5-minute return SD				
Mean	39	0.32	0.24	−0.08 (0.00)
Median	39	0.32	0.21	−0.07 (0.00)
Panel B: 5-minute return autocorrelation				
Mean	39	−0.04 (0.00)	0.01 (0.40)	0.05 (0.00)
Median	39	−0.04 (0.00)	−0.00 (0.40)	0.06 (0.00)
Panel C: variance decomposition (VAR(S))				
	Variance of noise (VAR(S))			
	Sample	NASDAQ (le-6)	NYSE (1e-6)	NYSE–NASDAQ (1e-6)
Mean	39	1.38	0.37	−1.01 (0.00)
Median	39	0.60	0.30	−0.30 (0.00)

5-min intervals fall after stocks switch listings to the NYSE and the reduction is significant. In addition to 5-min return volatility, we also examine daily volatility and 5-min price high–low ranges. The price high–low range is a simple and widely used volatility measure that gives particular weight to extreme values.[21] Studies have shown that the extreme value volatility estimators have good empirical performance and are closely related to market structure.[22] Our findings are consistent with previous evidence showing that return volatility declines on the NYSE. The economic magnitude for daily volatility reduction is

[21]We have screened our trade and quote data to exclude any problematic transactions or transactions that might have effects on the high-low range measure. In our study, we have excluded the following trades: trades done outside of the regular market hours of 9:30AM–4:00PM; cancelled Trades (CORR = 7–12 in TAQ), bunched trades (COND = B in TAQ), bunched sold trade (COND = G in TAQ), sold last trade (COND = L in TAQ), opened last trade (COND = O in TAQ), pre- and post-market close trades (COND = T in TAQ), average Price Trades (COND = W in TAQ), sold Sale (COND = Z in TAQ), and a trade in regular market hours whose price is 20% more or less than the previous trade. We also exclude the following quotes in our analysis: quotes outside the regular market hours of 9:30AM–4:00PM; quotes whose spread is greater than $2.00 or 10% greater than the quote midpoint; quotes whose midpoint rose or fell 20% or more from the previous quote midpoint; quotes associated with special market conditions, such as trading halts, news pending, or news dissemination. Overall, we have deleted less than 0.1% of the trades and quotes from the CT and CQ files.

[22]See Parkinson (1980), Li and Weinbaum (2000), Spurgin and Schneeweis (1997), among others.

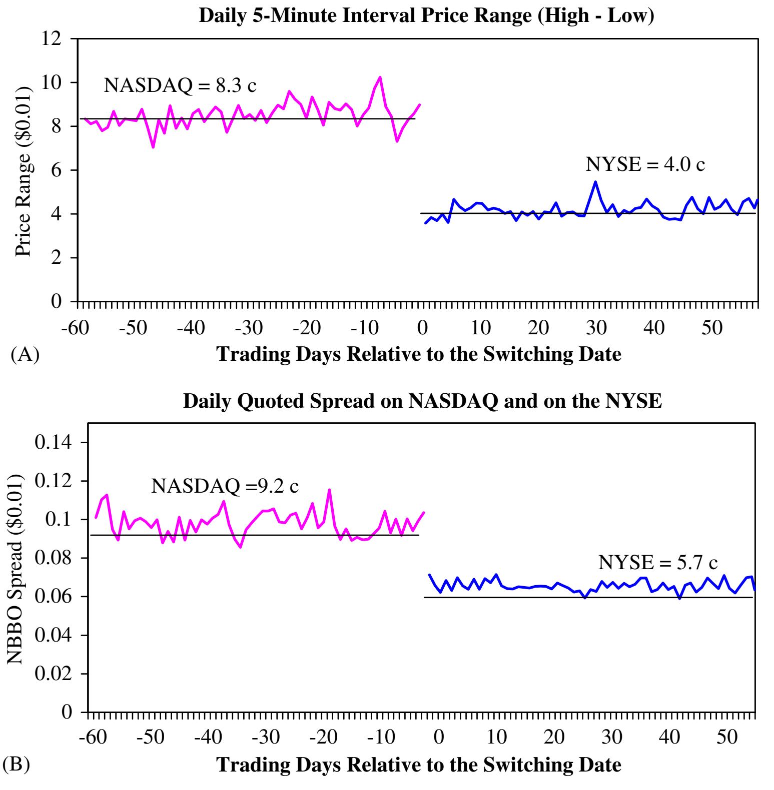


Fig. 2. Price range and quoted spread. The figure is the daily average of the NBBO quoted spread and the 5-min interval price range during (−60, +59) around transfers across 39 stocks. For price range, we divide a trading day into 78 5-min intervals. Interval #1 is from 9:30–9:35AM, and Interval #78 is from 3:55–4:00PM. Interval price range is defined as the difference between the interval high price and the interval low price. For each stock, we compute its daily average of interval price range across 78 intervals. Our sample includes the 39 stocks that have transferred their listings from NASDAQ to the NYSE during January 2002–March 2003. Our investigation window is (−60, +59) relative to each stock's transfer date, and our sample period is from October 2001 to January 2003.

comparable to that of 5-min volatility, but the magnitude for short-term price range reduction is larger. The daily return volatility declines from 3.4% to 2.7% after listing switches, marginally statistically significant at 1% level. The average 5-min price ranges fall by a significant amount, from 8.4 cents (31 bp) to 4.1 cents (20 bp). Checking robustness, we also use quote midpoints to measure price range, and examine 15-min and 30-min intervals. Overall we obtain qualitatively similar results.

Fig. 2(A) presents the daily average of 5-min interval price range during (−60, +59) around the switch. There is no apparent trend prior to or after the switches, consistent with the notion that the drop reflects market structure differences. The relative price change (normalized price range divided by interval closing price or quote midpoint) has a very similar pattern. We also examine the intraday patterns of the 5-min volatilities before and after switches. We find the volatility improvement is apparent all day long with the largest differences at the opening and close, reflecting the NYSE opening and closing auction procedures.

Volatility reduction, measured by the changes of return standard deviation as well as price high-low range, reflects the difference of market structures between the NYSE and NASDAQ in terms of consolidated order flow. The consolidation of order flows in an organized exchange encourages price competition and increases the likelihood that buy and sell orders interact with each other, mitigating price impact. In addition, the liquidity supply from the NYSE's specialists can also dampen transitory shocks on prices due to order imbalance.

2.2. Improvement of price efficiency

As noted, a decline in volatility improves market quality primarily to the extent that it eliminates price movements that are noisy or extraneous, not those that reflect the arrival of new information. Non-information based price movements may reflect liquidity characteristics of market structures also. The decentralized trading of a stock across a number of market centers, each with limited depth and providing a partial picture of order flows, might lead to price fluctuation for liquidity reasons, although the pure noise swings could be expected to be at least partially unwound subsequently. In a well-functioning market, the prices in one period would be essentially uncorrelated with subsequent prices, with neither positive nor negative auto-correlation, and the noise component of prices would be small.

We use three measures to examine price efficiency. The first is the return autocorrelation. To control for the bid-ask bounce, we also compute autocorrelations based on quote midpoints. The second measure for examining price efficiency is based on the Hasbrouck (1993) variance decomposition. Hasbrouck (1993) decomposes the variance of transaction price into variance of efficient price and the variance of noise. The approach separates the noise variance component of price movements from the information-based variance component. The last measure of price efficiency is the variance ratio test. We compare the variance of price returns in two separate 5-min periods with the variance over the combined 10-min period. If the prices are not affected by autocorrelation, the variance ratios should be equal to one. If they are negatively auto-correlated, then the variance in the overall 10-min period would be less than the sum of variances in the two five minute periods, resulting in a smaller variance ratio. All the above results reach the same conclusion: price efficiency improves on the NYSE. We report the results of 5-min return autocorrelation and Hasbrouck (1993) decomposition in Table 4 panel B and C, and omit the variance ratio results to save space.

We measure return a couple of different ways, using daily, 5-min interval, open-to-open, and close-to-close. Results based on various methods only differ in magnitude and are similar qualitatively. The results in Table 4 are returns measured using quote midpoints and close-to-close intervals of 5-min intervals. Overall, we find price efficiency improves when the stocks switch from NASDAQ to the NYSE. The auto-correlation of returns based on quote midpoint movements, as shown in Panel A of Table 4, changes a statistically significant amount to be closer to zero. Panel B shows that the variance of pricing error, following the Hasbrouck (1993) variance decomposition approach, drops as well, both by a statistically and economically significant amount. The standard deviation of the trade-by-trade pricing error is about 0.12 cents on NASDAQ, and it drops by half

Table 4
Change of quoted spread, effective spread, and realized spread

We report the changes of quoted, effective and realized spreads in Panels A, B, and C. Our sample includes the 39 stocks that have transferred their listings from NASDAQ to the NYSE during January 2002 to March 2003. We recompile the National Best Bid and Offer (NBBO) from TAQ. NBBO quoted spreads are time-weighted. We obtain the order level effective and realized spreads from monthly Dash5 reports. For each stock in each month, we compute the share-weighted effective and realized spreads. We conduct the t tests for the mean difference and the Wilcoxon test for the median difference, and provide p values. Our investigation window is (−3, −1) for NASDAQ and (+1, +3) for the NYSE relative to each stock's transfer month ($t = 0$). We exclude the month in which the stocks switched. Our sample period covers from October 2001 to June 2003.

Panel A: quoted spread

	Quoted spread ($0.01)			Quoted spread relative to price (bp)		
	NASDAQ	NYSE	NYSE-NASDAQ	NASDAQ	NYSE	NYSE-NASDAQ
Mean	9.19	5.94	−3.25 (0.00)	37.13	27.33	−9.80 (0.01)
Median	7.63	5.84	−1.71 (0.00)	31.57	23.37	−4.90 (0.00)

Panel B: effective spread

	Effective spread (ES) ($0.01)			Effective spread relative to price (bp)		
	NASDAQ	NYSE	NYSE-NASDAQ	NASDAQ	NYSE	NYSE-NASDAQ
Mean	8.50	5.57	−2.93 (0.00)	34.03	25.30	−8.72 (0.00)
Median	6.51	5.02	−1.12 (0.00)	28.34	23.13	−3.10 (0.00)

Panel C: realized spread

	Realized spread (RS) ($0.01)			Realized spread relative to price (bp)		
	NASDAQ	NYSE	NYSE-NASDAQ	NASDAQ	NYSE	NYSE-NASDAQ
Mean	4.51	−0.42	−4.93 (0.01)	16.66	−0.51	−17.18 (0.00)
Median	1.75	−0.23	−2.01 (0.00)	6.21	−0.01	−6.50 (0.00)

on the NYSE. The variance ratio tests also show that NASDAQ's ratio (0.85) is significantly lower than the NYSE (0.91), reflecting a larger short term price fluctuation on NASDAQ. Further analysis shows that volatility is much higher on NASDAQ at the opening and closing trading. In order to separate opening and closing effect on volatility, we replicate the above tests during 9:45AM–3:45PM, excluding the first and last 15 min of trading. We obtain similar results, suggesting that the higher transitory volatility on NASDAQ is not solely driven by opening and closing trading.

The improvements in the various measures of price efficiency are statistically significant, and the reduction of volatility of switching stocks is mainly due to the reduction of noise and transitory pricing error. As a result, the decreasing of volatility for the switching stocks contributes to improvements of pricing efficiency.

3. Effects of switching on spreads and execution speed

Quoted spreads compensate liquidity suppliers for providing liquidity and bearing risks due to adverse selection, and realized spreads are the payoff after control for information asymmetry. The fact that higher competition is associated with order flow consolidation on the NYSE suggests that quoted spreads would narrow and effective spreads would fall as well.[23] In this section we examine how declines in volatility and improvements in price efficiency and order flow consolidation affect spreads after stocks switched to the NYSE. Besides spread measures, we also look at execution speed, which is another dimension of execution quality. Holding other things equal, faster execution is preferred.

We derive the National Best Bid and Offer (NBBO) from the TAQ database. We also have effective spreads, realized spreads, and execution speed from the SEC 11Ac1–5 reports. Because these 11Ac1–5 statistics are conditional on order type and size, we weight effective spreads and execution speed by executed shares. As in the preceding section, we use 60 trading days pre- and post-switch windows in studying quoted spreads from the NBBO files. When using the (monthly) 11Ac1–5 data, we compare 3 months of data prior to and 3 months after each of the switches, skipping the switching month. We present the evidence of changes of quoted spread, effective spread, and realized spread in Panels A, B, and C in Table 4.

3.1. Changes in quoted spreads

Panel A of Table 4 shows that quoted spreads fall after stocks switch to the NYSE. The quoted spreads on average drop by 3 cents (10 bp) with statistical significance. In order to analyze whether the spread change has economic significance, we normalize the spread reduction to pre-switch NASDAQ quoted spread and compute the percentage change. We find, across the stocks, the spread change reflects 16% (25% in median) reduction of NASDAQ spread. The reduction of quoted spread in time series is reported in Fig. 2(B). Fig. 2(B) also shows the NASDAQ daily NBBO average quoted spread has a larger time variation. The coefficient of (day to day) variation for NASDAQ quotes is 69.8%, compared with 46.7% for the NYSE quote, suggesting liquidity on the NYSE is more stable.[24]

Besides the NBBO spreads, we also examine quoted spreads in the SEC 11Ac1–5 data, which are conditional on order arrivals. Examination of the Dash5 quoted spread, therefore, is more closely related to the market liquidity when it is needed. Overall, we find that the results from the Dash5 quoted spread are similar to the NBBO quoted spread. Further analysis shows that the NYSE average quoted spreads are tighter throughout the trading day with the improvement particularly larger at the opening and the close. Evidence in Fig. 2 is not solely due to opening or closing trading. The difference in quoted

[23] A different hypothesis might be, for example, that the 5 min price volatility differences between the NYSE and NASDAQ reflect the dispersion of liquidity on NASDAQ and the associated idiosyncratic risk of pushing prices up when buying or down when selling at a particular market center. But if these mismatches of demand and supply of liquidity were idiosyncratic, unconnected events, then these risks would be diversifiable and would not necessarily imply that the inside quotes would be wider on the NASDAQ market. On the other hand, if the dispersed market structure created not only more price volatility but also more undiversifiable risk for dealers or limit order providers due to less complete information about order flow and market direction, then the quotes would be wider as well. Similarly, the effective spread, reflecting the (required) execution cost in the competitive market should also be narrower in a market with a lower price volatility and better information.

[24] The coefficient variation is defined as the ratio between the standard deviation and the mean. The standard deviation for the daily NBBO quote spread is 0.00641 for NASDAQ and 0.00279 for the NYSE. The coefficient of variation for NASDAQ quotes is $0.00641/0.0919 = 69.8\%$, and the coefficient of variation for NYSE quotes is $0.00279/0.0597 = 46.7\%$.

spreads reflects the competition of order flows and market structure between NASDAQ and the NYSE.

3.2. Changes in effective spreads and realized spreads

We next examine the effects of switching listings on execution costs, using effective spreads from the 11Ac1–5 data. These effective spread measures are of interest in the current context because they compare execution prices with order-arrival-time quote midpoints. Panel B of Table 4 shows that effective spreads decline when the stocks shift to the NYSE. On average, the per-share effective spread across the 39 stocks decreases by 3 cents (9 bp) after the switch with statistical significance. When normalizing the effective spread reduction to the pre-switch NASDAQ effective spread, the percentage change is about 19% in mean and 11% in median across the stocks, all with statistical significance. The reduction of effective spreads is related to the reduction of volatility and quoted spreads, and further indicates the positive impact of order flow consolidated on the NYSE on execution cost.

An alternative way to measure transaction costs is developed by Hasbrouck (1993). Following this method, we calculate the expected transaction costs to be 14.1 basis points on NASDAQ and 4.8 basis points on the NYSE.[25]

Examination of realized spread indicates that intermediaries earn higher rents for supplying liquidity on NASDAQ than on the NYSE. On average, realized spreads are positive on NASDAQ and negative on the NYSE. The reduction of realized spread is significant and the magnitude, on average about 6 cents (18 bp), is economically meaningful. The evidence suggests that the competition for supplying liquidity on the NYSE is higher than on NASDAQ, and intermediaries including specialists, floor traders, and public limit orders all supply liquidity when it is needed on the NYSE. Our findings are consistent with literature showing that the NYSE provides more liquidity when markets have high volatility and market uncertainty.

Dash5 effective and realized spreads are only for orders smaller than 10,000 shares. The data are also not audited and are subject to possible data errors.[26] In a robustness check, we compute effective and realized spreads using TAQ data, which do not have actual trade direction and order arrival time. Nevertheless, TAQ spread is widely used as an execution cost measure. We reach the same conclusion using TAQ effective and realized spreads.

3.3. Changes in execution speed

Finally, we present execution speed. We share weight execution speed from Dash5 reports in aggregation and separate the analysis by order type and size. We find the NYSE faster for market orders, but NASDAQ is faster overall and across all size categories. On

[25]In Hasbrouck (1993), the expected transaction cost can be computed as the expected value of the deviation, $\mathrm{E}|S_t| = \sqrt{\frac{2}{\pi}}\sigma_s$. Using the average variance of deviation reported in Table 6, we can get the expected transaction cost for NASDAQ: $\mathrm{E}|s_t| = \sqrt{\frac{2}{\pi}}\sigma_s = 0.8 * (\mathrm{SQRT}(1.17\mathrm{e}-6)) = 0.8 * (0.00176) = 0.00141$; and the expected transaction cost for the NYSE: $\mathrm{E}|s_t| = \sqrt{\frac{2}{\pi}}\sigma_s = 0.8 * (\mathrm{SQRT}(0.61156\mathrm{e}-6)) = 0.8 * (0.0006) = 0.00048$.

[26]In October 2005, Instinet and Island were fined by the SEC due to their inaccurate 11Ac1–5 data.

average, the execution speed is 25 seconds on NASDAQ and 50 on the NYSE. The slower execution speed on the NYSE is due to manual execution and the auction market mechanism. We omit the results here to save space.

4. Selection bias

4.1. Sample comparison

The 39 companies that switch from NASDAQ to the NYSE are not randomly selected. If the switching companies are not typical of NASDAQ firms who are eligible to switch, then the before-and-after analysis might contain statistical biases. One check on this is to compare the firms that have switched with those that do not. As Table 1 illustrates, the 39 stocks that have switched have median values of the observable measures that are similar to the median values of all the eligible NASDAQ firms.

4.2. Matching sample

A more elaborate check is to match the switching stocks with non-switching NASDAQ stocks, based on observable characteristics, and see whether and how volatility and spreads for these "sister" stocks changed before and after switching. We match each of the 39 stocks by market cap, trading volume, price, and return volatility from the NASDAQ universe.[27] We replicate our examination on volatility, price efficiency, and market measures for these 39 NASDAQ matching stocks during the same event window, and find all of the above measures do not have significant (either economically or statistically) changes for the non-switching group. The evidence suggests that the changes observed for the switchers are due to the listing change, rather than selection bias. We have the detailed sample statistic results of the 39 matching stocks as well as the examination results on volatility, price efficiency, and market quality. We omit them to save space, but the results are available upon request from the authors.

4.3. Two-stage selection model

Using a matching sample to control for selection bias is intuitive, but may not be sufficient due to the limitation of finding a perfect match. A more rigorous approach to controlling and correcting the bias is to use a two-stage selection model developed in Heckman (1979). If we use the OLS model to examine the impact of firm characteristics and market structure on improvements of market quality, our estimates would be biased if using only the 39 stocks. This is because our sample is a restricted and nonrandom one, meaning that we can only observe the changes of market quality for 39 firms who have switched, but not for those who have not switched. The Heckman's two-stage selection procedure can correct such a selection bias issue.

The two-stage selection procedure first uses a PROBIT model to explain the influences of a number of firm characteristics on a company's decision to switch listing and to estimate the probability of doing so. From the PROBIT equation, we obtain the predicted switching probabilities (fitted values) for each of the 39 firms, and use these values to

[27]We use the same matching criteria used in the SEC (2001).

compute a control variable, Heckman's Inverse Mills' Ratio (IMR), for selection bias which will be used in the second stage OLS regression. The IMR is defined as $\lambda_j = \varphi(\rho_j)/\Phi(\rho_j)$, where ρ_j $(j = 1, 2, \ldots, 39)$ is the predicted probability of switching; $\varphi(\rho_j)$ is the standard normal density function (pdf); $\Phi(\rho_j)$ is the standard normal distribution function (cdf). The second stage OLS regression is to examine the impact of order flow fragmentation on market quality changes after controlling the selection bias and firm characteristics. The following two OLS regressions are run in the second stage:

$$\frac{\text{NASDAQ} - \text{NYSE}}{\text{NASDAQ}} j = \alpha + \beta_1 \log(\text{mcap}_j) + \beta_2 \log(\text{volume}_j) + \beta_3 \text{HHI}_j + \beta_4 \text{IMR} + \varepsilon_j, \tag{1}$$

$$\frac{\text{NASDAQ} - \text{NYSE}}{\text{NASDAQ}} j = \alpha + \beta_1 \log(\text{mcap}_j) + \beta_2 \log(\text{volume}_j) + \beta_3 \log(\text{MCNUM}_j) + \beta_4 \text{IMR} + \varepsilon_j, \tag{2}$$

where $\text{NASDAQ}-\text{NYSE}/\text{NASDAQ}_j$ stands for the percentage changes of market quality (return volatility and spread) for stock j $(j = 1, 2, \ldots, 39)$. Since the percentage change compares the reduction in volatility and spread to the pre-switch NASDAQ level, it indicates the economic significance of the improvement. Using it as the dependent variable in the regression, we hope to study the relationship between the economic significance of market quality improvement and fragmentation.

HHI is the Herfindahl–Hirschman Index (HHI), measuring the order flow concentration (fragmentation) on NASDAQ. It is based on the distribution of the number of orders that are covered in 11Ac1–5 reports across market centers. Besides the HHI, we also use the number of market centers that trade for a given stock (MCNUM) on NASDAQ as a proxy of market fragmentation. Holding other things equal, if stock j has a higher degree of order flow fragmentation on NASDAQ, HHI is smaller and MCNUM is larger. Both proxies for market fragmentation are reported in Table 2 and Fig. 1 shows the monthly HHI. We control the regressions by firm characteristics, such as market capitalization and trading volumes.

In the first stage PROBIT regression, we include explanatory variables that try to predict which firms will switch. A probabilistic approach makes sense because the switching decision involves one-time and continuing costs and may be costly to reverse. A company has to reach the decision to switch from NASDAQ to the NYSE based on a comparison of these costs with the expected benefits to shareholders over time. For example, most firms would pay a higher ongoing listing fee when they switch to the NYSE, in addition to a one-time payment.[28] Uncertainty about future growth, recognition lags about the benefits of

[28] A hypothetical median firm in our sample, with 30 million outstanding shares, would under current NASDAQ National Market rules be paying \$29,820 annual listing fees (in addition to an original NASDAQ listing fee of \$100,000). On the NYSE, such a firm would pay a \$172,000 original fee plus a \$35,000 annual listing fee. In other words, if such a firm transferred from NASDAQ to the NYSE, the incremental amount that it would pay to the NYSE in this example would be a one-time \$172,000 fee plus a higher annual amount of \$5,180 (\$35,000 less \$29,820). The present value of the cost associated with the switch, if valued at an average 5% long-term annual rate, is \$275,700, assuming the firm lives forever and does not increase its market capitalization and shares outstanding. For more detailed and updated information of the listing fee of the NYSE and NASDAQ, see www.nyse.com and www.nasdaq.com.

switching, and other unknowns in the cost-benefit comparison may make the decision of whether and when to switch listings observationally probabilistic.

The PROBIT regression uses an uncensored sample of all NASDAQ stocks that appear to meet the NYSE listing standards and can choose to switch. We gather the company information that relates to the NYSE listing standards, such as the number of round-lot shareholders, monthly volume, market capitalization, the number of shares outstanding, pretax earnings, and operating cash flow from the CRSP and COMPUSTA datasets.[29] We identify 663 companies from over 3600 NASDAQ-listed firms that appear to meet the NYSE listing standards as of December 2001. We find market capitalization and trading volume to be the most binding variables in selecting the eligible NASDAQ stocks for listing on the NYSE.[30] The sample of 663 stocks includes the 39 companies that subsequently switched. We exclude three companies from the 663 NASDAQ NYSE-eligible sample due to data missing in the CRSP or Compustat. As a result, our sample size in the NASDAQ NYSE-eligible sample is 660. We estimate the following PROBIT model across the 660 companies:

$$\begin{aligned} P_j(\text{switch}) = \alpha &+ \beta_1 \ln(\text{mcap}_j) + \beta_2 \ln(\text{shareout}_j) + \beta_3 \ln(\text{volume}_j) \\ &+ \beta_4 \ln(\text{price}_j) + \beta_5 \ln(\text{mmcnt}_j) + \beta_6(\text{volatility}_j) + \beta_7(\text{return}_j) \\ &+ \beta_8(\text{spread}_j) + \beta_9 \ln(\text{distance}_j) + \beta_{10} \ln(\text{SICmg\_num}_j) \\ &+ \beta_{11}(\text{ex\_cindex}_j) + \varepsilon_j, \end{aligned} \tag{3}$$

where P_j (switch) is the probability of switching, having value of 1 for the 39 transferred companies and zero otherwise; mcap is market capitalization, the product of the number of shares outstanding and the price; price is the daily average closing price; shareout is the number of shares outstanding; volume is the daily trading volume in shares; mmcnt is the number of registered NASDAQ market makers; volatility is measured as the standard deviation of daily close-to-close returns; spread is the ratio of the bid-ask spread to quote midpoint at daily close. Besides the above commonly used firm characteristic variables that we think may influence firms' decision to switch, we include three additional variables in the regression to explain the choice. Distance is the geographic distance between the firm to the New York Stock Exchange, measured between the New York City and the capital city of the US state in which the firm is located as of December 2001. This variable is an instrumental variable that is uncorrelated with market quality. The other two variables are industry concentration, which may influence firms' choice of listing (Baruch et al., 2005). SICmg_num is the total number of listed companies in the major group of the Standard Industry Classification (SIC) to which a firm belongs. Ex_cindex is the Exchange Industry Concentration Index developed in our study, defined as the ratio between the total market cap of all NASDAQ NYSE-eligible firms to the total market cap of the NYSE firms and the NASDAQ NYSE-eligible firms in the SIC major group. Ex_cindex is an increasing function of industry concentration on NASDAQ. Appendix B provides the details on the industry concentration statistics.

[29]For the detailed NYSE listing standards for the domestic companies, please see Section 102.00 of the NYSE Listed Company Manual.

[30]The NYSE listing standards requires that the company have at least 500 round-lot shareholders if it has at least 1,000,000 shares monthly trading volume in the last 12 months, or 2,200 round-lot shareholders if the average monthly trading volume is at least 100,000, or 2,200 round-lot shareholders.

All the above variables are estimated during the period from January to December 2001. The results show that trading volume, the registered market maker number, the daily return, and the exchange industry concentration index have significant explanatory power in the PROBIT model. The evidence suggests that when the stocks have experienced positive returns and are active, they have a lower tendency to switch listings. Of particular interest, we have found that stocks with a higher number of NASDAQ market markers tend to switch, suggesting that order fragmentation may play a role. Besides the above variables, daily return volatility is marginally significant, implying that stocks with higher daily return volatility tend to switch to the NYSE. We omit the estimation results here.

In addition, the evidence from the exchange industry concentration index suggests that the higher the industry concentration on NASDAQ, the higher the probability that companies leave NASDAQ and switch to the NYSE. For example, industry group 73 is one of the top 15 SIC major groups with the highest NASDAQ concentration index, about 56%.[31] Among the 39 transferred stocks, we have four companies in the "73" SIC major group. The PROBIT model indicates that although this group is over-represented on NASDAQ, these companies' probability of switching to the NYSE are relatively high.

For sensitivity analysis, we also use two other variables in the regression in replacing the SICmg_num: (1) the total market capitalization of listed companies in each of the SIC industry major groups, and (2) the total market capitalization of the listed companies on NASDAQ in each of the SIC industry major groups. Including these does not materially affect the estimates. In addition, we also replace the daily return volatility with the daily average price range, measured as the ratio of the difference of daily high and low price to the daily closing price, and the results are little changed. In addition, changing the sample period from January 2001–December 2001 to the second half year of 2001 does not alter our results.

After we obtain the fitted value ρ_j from the first stage PROBIT regression, we compute the inverse Mills ratio as $\lambda_j = \varphi(\rho_j)/\Phi(\rho_j)$. We then insert the inverse Mills ratio as a variable into the second-stage regression to control for selection bias. The second stage regression aims to explain improvements in volatility and spreads conditional on firm characteristics and the degree of fragmentation in that stock. The results are reported in the next section, Section 5.

5. Fragmentation effects

We run a cross sectional regression between the percentage change of market quality and fragmentation to study whether order flow fragmentation affects market quality. We use market cap and trading volume as controls. We also insert the inverse Mills ratio to control for possible selection bias. We use two measures as proxies of market fragmentation: the Herfindahl–Hirschman Index (HHI), based on the distribution of the number of orders that are covered in 11Ac1–5 reports across market centers, and the number of market centers that trade for a given stock (MCNUM). We also develop HHI_ratio (HHI_ NASDAQ/HHI_NYSE) and

[31] The "73" SIC industry group is classified as "Business Service" by the US Census Bureau. Microsoft (MSFT) is in this group.

MCNUM_ratio (MCNUM_NASDAQ/MCNUM_NYSE) to capture the change of fragmentation between NASDAQ and NYSE. The dependent variables are the percentage changes of market quality, measured as 1–NYSE/NASDAQ (normalize the change by NASDAQ). As explained in the previous section, we construct the dependent variable in such a way as to focus on the economic significance of the change.

If fragmentation affects market quality, we should expect stocks with a higher order fragmentation (smaller HHI and larger MCNUM) to experience larger improvements in liquidity and efficiency after switching to the NYSE, resulting in a negative coefficient on HHI and positive on MCNUM. Table 5 shows the results for 5-min volatility, NBBO quoted spread, and effective spread. Indeed, consistent with the theory, the fragmentation coefficients have the expected signs and are statistically significant. A higher degree of order flow fragmentation on NASDAQ is associated with a larger reduction in volatility and spread as shown in Model 1 and Model 2 after controlling for firm characteristics and selection bias (IMR).

Results in Models 3 and 4 further indicate that the improvements on order flow fragmentation, captured by HHI_ratio and MCNUM_ratio, after switches also have a strong power to explain the cross sectional variation of market quality changes across the sample stocks. The evidence suggests that the improvement in order flow consolidation on the NYSE contributes to the changes in market quality: a higher degree of consolidation on the NYSE leads to a relatively larger improvement. We also run the regression for daily volatility and obtain similar results.

In addition, we find stock liquidity affects the magnitude of improvements. The fact that the regression coefficient on trading volume is negative and significant indicates that less liquid stocks experience larger improvement with order flow consolidation. Our finding is consistent with the theory that order flow consolidation is particularly valuable for less liquid stocks.

The inverse Mills ratio coefficients in Panels A and D are not statistically significant, suggesting that a severe selection bias does not exist. The ratio is significant in B, suggesting that a selection bias exists with respect to quoted spread, so that firms with worse liquidity on NASDAQ (wider quoted spread) tend to move to the NYSE. Our estimates, however, are unbiased since the IMR has corrected the selection bias.

We also make use of Dash5 data to further examine the impact on effective and quoted spreads across order type and order size. We find on average small-sized orders (100–2000 shares) and market orders benefit the most in terms of liquidity after trading on the NYSE. Our evidence is consistent with the findings in Boehmer (2005), and suggests a higher degree of order flow interaction benefits smaller orders. For larger and marketable limit orders, the difference exists but with weak statistical significance. We omit the above results to save space.

We conduct several robustness checks to assure our results. In Table 5, our dependent variables are proportional changes, namely relative to the NASDAQ levels. Using the simple changes (NASDAQ–NYSE) or the spread in dollar or basis points does not alter our results materially. We reach the same conclusion if using the spread estimates from TAQ or Dash5. We find using price as a control variable has little explanatory power, reflecting that the changes of market quality do not relate to the stock's price level.

Table 5
Impact of fragmentation on the reduction of volatility and spreads

We run cross sectional regressions between the relative changes of market quality on the fragmentation proxy and other control variables. Our sample is the 39 switching stocks. Market cap and daily volume are the monthly averages during (−3, −1) from the CRSP. Daily volatility is measured as the standard deviation of the daily return during (−60, −1). Herfindahl-Hirschman Index (HHI) and the number of market centers (MCNUM) are our proxies for fragmentation, computed from Dash5 data. IMR(Inverse Mills Ratio) is from the Heckman first stage probit regression. HHI Ratio is computed as HHI (NASDAQ)/HHI(NYSE). MCNUM Ratio is log(NASDAQ_mcnum)/log(NYSE_mcnum). Each regression has 39 observations. Dash5 data is (−3, −1) for NASDAQ and (+1, +3) for the NYSE relative to each stock's switching month. The sample period covers from October 2001 to June 2003. Dependent variables are measured as the changes relative to pre-switch level: (NASDAQ–NYSE)/NASDAQ = (1–NYSE/NASDAQ). ***, **, and * indicate better than 1%, 5%, and 10%, significance.

Panel A: dependent variable: change of 5-min standard deviation volatility (1-NYSE/NASDAQ)				
Constant	1.31***	2.99***	1.14***	1.58***
Log (mcap)	0.06	−0.03	0.02	−0.005
Log (volume)	−0.06*	−0.24***	−0.03	−0.13***
HHI	−1.39***			
Log (MCNUM)		0.02***		
HHI ratio			−1.06***	
MCNUM ratio				0.12***
IMR	0.13	0.16	0.08	0.08
R_2	0.53	0.44	0.53	0.41
Panel B: dependent variable: change of NBBO quoted spread (1-NYSE/NASDAQ)				
Constant	2.54***	3.70***	2.25***	2.72***
Log (mcap)	0.26**	0.16	0.25***	0.20**
Log (volume)	−0.32***	−0.42***	−0.29***	−0.39***
Daily volatility	0.02	0.003	0.03*	0.01
HHI	−1.39**			
Log (MCNUM)		0.02**		
HHI ratio			−1.58***	
MCNUM ratio				0.15**
IMR	0.82***	0.83***	0.78***	0.80***
R_2	0.69	0.66	0.75	0.67
Panel C: dependent variable: change of effective spread (1-NYSE/NASDAQ)				
Constant	1.59***	2.82***	1.38***	1.64***
Log (mcap)	0.04	0.002	0.05	0.04
Log (volume)	−0.12***	−0.26***	−0.10***	−0.19***
Daily volatility	0.02	0.01	0.02	0.01
HHI	−0.72*			
Log (MCNUM)		0.02**		
HHI ratio			−0.97**	
MCNUM ratio				0.16**
IMR	0.13	0.21	0.11	0.15
R_2	0.41	0.43	0.45	0.42

6. Conclusion

We study the impact of order flow consolidation on liquidity provision and market quality by using the natural experiments of exchange switching. Due to differences in market structure, NASDAQ stocks are traded by a large number of market venues and have a higher degree of order flow fragmentation than their NYSE peers. When NASDAQ stocks switch listing to the NYSE, order flows migrate from dealers and ECNs to the exchange and become more consolidated. Such natural experiments allow us to examine the impact of market fragmentation on liquidity provision and price efficiency.

On average stocks have experienced improvement in market quality and price efficiency on the NYSE. We find that the pre-switch degree of order flow fragmentation on NASDAQ has a strong explanatory power for the post-switch market quality improvements on the NYSE, implying that companies with more fragmented trading on NASDAQ experienced larger improvements in market quality when switching to the NYSE, *ceteris paribus*. In addition, we also find stock liquidity is negatively correlated with the post-switch reduction in price inefficiency and execution cost, suggesting that the order flow consolidation is particularly more valuable for less liquid securities.

Our results show that order flow consolidation has incremental value above and beyond the measures to improve inter-market competition, transparency, and efficiency. One key to the market quality of the NYSE is closely associated with the consolidation of order flows. These results underline the importance of order flow consolidation in a single primary market where buy and sell orders can interact competitively and prices can be discovered efficiently. These findings do not appear affected by a sample selection bias.

Our study complements other work in the area of optimal market structure. Volatility and execution cost are important dimensions of market quality, but they are not the full story of it. Another dimension of market quality is related to a market's ability to handle stress and liquidity shock. Barclay et al. (2003) demonstrate that the NYSE's better performance over NASDAQ in handling liquidity shock and market stress is related to order flow consolidation in the auction market. Elliott and Warr (2003) show that the NYSE's ability to adjust more quickly to liquidity shocks than NASDAQ stocks is due to NYSE's market structure and consolidation of liquidity. Examining trading post the 9-11 event, Chung and Kim (2005) conclude that the NYSE's market structure works more efficiently than NASDAQ in handling extreme market conditions and uncertainty. Studying fragmentation and a market's ability to handle stress has many implications which we leave for future research.

In short, while market center competition has important beneficial effects on market functioning, the economics of order flow consolidation appear to be a dominant factor in determining how well markets provide liquidity and form prices that allocate capital efficiently.

Appendix A

Information for the 39 transferred NASDAQ stocks is given in Table 6.

Appendix B

Exchange industry concentration summary is given in Table 7.

Table 6
We report sample statistics for the 39 firms that switch from NASDAQ to the NYSE
Volatility is the standard deviation of daily return. Our sample window is 60 days prior to the switches. Our investigation period is October 2001 to January 2003.

Company name	Transfer date	Market cap ($ 000)	Volatility* (%)	Closing price ($)	Daily volume (share)	Medium trade size (share)	Mean trade size (share)
RailAmerica, Inc.	1/2/2002	345,507	2.628	12.65	195,527	309	1,019
Network Associates, Inc.	2/12/2002	4,152,265	4.108	25.99	3,870,573	227	799
Old National Bancorp	2/15/2002	1,474,259	0.846	24.46	49,445	170	545
Action Performance Group	2/20/2002	696,643	3.867	34.66	424,148	117	461
The Bisys Group Inc.	3/6/2002	3,741,776	6.652	58.81	539,655	112	487
Clark/Bardes, Inc.	3/7/2002	420,218	2.883	24.83	45,150	148	439
Regions Financial Corporation	5/3/2002	8,054,141	0.972	33.66	562,085	103	340
Tom Brown, Inc.	5/16/2002	1,135,582	1.461	27.66	150,718	126	380
Astoria Financial Corporation	5/17/2002	2,890,475	1.174	30.86	555,388	128	517
The Nautilus Group, Inc.	5/21/2002	1,567,853	2.974	37.37	966,672	162	356
Cantel Medical Corp	5/29/2002	159,748	4.804	24.52	36,053	194	414
Province Healthcare Company	6/5/2002	1,214,086	4.955	29.38	552,492	158	461
The CATO Corporation	6/13/2002	523,859	2.466	24.97	105,593	148	505
Remington Oil & Gas Co.	6/20/2002	503,502	2.662	19.62	153,780	148	438
Emulex Corporation	6/24/2002	2,458,602	5.819	29.11	8,521,118	202	422
Oshkosh Truck Corporation	7/12/2002	973,246	3.328	58.32	82,577	103	287
Christopher & Banks Co.	7/17/2002	1,077,889	3.107	39.92	357,183	100	289
CACI International Inc.	8/16/2002	973,895	4.054	33.91	518,490	102	288

Select Medical Corporation	8/28/2002	674,228	2.819	14.45	142,488	112	313
Valmont Industries, Inc.	8/30/2002	523,109	3.527	20.30	59,138	108	274
Genesse & Wyoming Inc.	9/27/2002	289,238	3.645	20.68	61,750	109	326
BearingPoint, Inc.	10/3/2002	1,224,357	5.263	9.78	1,399,358	177	551
Greif Bros. Corporation	10/7/2002	259,259	3.276	26.15	16,042	106	276
Webster Financial Corp.	10/17/2002	1,610,396	2.378	35.39	278,221	100	294
Stewart & Stevenson Services	10/18/2002	1,124,613	2.218	24.94	330,586	102	280
Waste Connections, Inc.	10/24/2002	967,440	2.409	33.79	265,037	105	297
Banknorth Group, Inc.	11/4/2002	3,428,326	2.306	24.43	824,466	123	363
Getty Images, Inc.	11/5/2002	1,532,737	4.792	20.17	439,202	115	316
Concord EFS, Inc	11/7/2002	7,326,140	5.581	16.74	9,869,623	222	644
Right Management Consultants	11/15/2002	298,646	5.873	19.79	171,485	107	263
St Mary Land & Exploration Co.	11/20/2002	705,896	2.170	24.34	124,143	100	284
H.B. Fuller Company	12/2/2002	821,386	2.565	28.20	88,341	100	198
Interactive Data Corporation	12/10/2002	1,430,755	2.060	13.91	210,244	114	336
Alliance Gaming Corporation	12/12/2002	845,261	3.464	16.33	588,430	152	391
New York Community Bancorp	12/20/2002	2,988,178	2.351	28.23	887,826	107	357
CPB Inc.	12/31/2002	412,946	6.846	36.59	18,008	102	193
AMERIGROUP Corporation	1/3/2003	619,203	3.534	30.41	331,506	100	298
Offshore Logistics, Inc	3/12/2003	493,222	2.871	20.27	109,989	100	251
Regis Corporation	3/27/2003	279,012	3.301	11.88	222,738	107	382

Table 7
We report the top 15 major groups of the Standard Industry Classification (SIC) that have the highest Exchange Industry Concentration Index by Firm Mcap for the NYSE and NASDAQ, respectively

The Exchange Industry Concentration Index by Firm Number (EICIFN) is computed as the ratio between the number of NASDAQ firms, who are eligible for the NYSE listing standards, in a particular SIC major group to the total number of the sum of the NYSE firms and the NASDAQ NYSE-eligible firms in the SIC major group. The Exchange Industry Concentration Index by Firm Mcap (EICIFM) is computed as the ratio between the total market cap of all NASDAQ NYSE-eligible firms to the total market cap of the NYSE firms and the NASDAQ NYSE-eligible firms in the SIC major group. The sample estimation period is January 1, 2001 to December 31, 2001.

CRSP SIC Major Group Code	Standard industrial classification (SIC) code descriptions by the US census bureau	Industry market cap ($M)	NASDAQ market cap ($M)	Industry firm number	NASDAQ firm number	Exchange industry concentration index by firm number (EICIFN)	Exchange industry concentration index by firm mcap (EICIFM)
41	Local and interurban transit	309.28	309.28	1	1	1.00	1.00
47	Transportation services	7,293.73	7,159.75	7	6	0.86	0.98
82	Educational services	13,821.52	10,915.41	11	8	0.73	0.79
42	Trucking and warehousing	13,871.72	9,455.44	15	11	0.73	0.68
73	Business services	1,279,835.49	691,960.57	187	104	0.56	0.54
87	Engineering & management services	57,403.27	30,933.67	41	16	0.39	0.54
36	Electronic equipment	1,297,002.23	607,098.60	163	88	0.54	0.47
78	Motion pictures	9,638.43	3,567.92	5	2	0.40	0.37
23	Apparel and other textile products	24,903.18	8,569.05	15	2	0.13	0.34
83	Social services	1,027.17	343.55	3	1	0.33	0.33
57	Furniture and homefurnishings stores	40,147.49	13,223.17	15	7	0.47	0.33

16	Heavy construction, ex. building	6,184.42	1,683.22	8	3	0.38	0.27
35	Industrial machinery and equipment	696,221.84	187,318.44	122	30	0.25	0.27
58	Eating and drinking places	78,815.81	18,005.91	35	14	0.40	0.23
59	Miscellaneous retail	88,005.06	18,485.56	29	8	0.28	0.21
20	Food and kindred products	460,721.95	5,305.17	53	8	0.15	0.01
49	Electric, gas, and sanitary services	435,958.63	3,707.05	112	6	0.05	0.01
29	Petroleum and coal products	426,471.59	419.04	19	1	0.05	0.00
1	Rice corn soybeans	1,498.64	0.00	1	0	0.00	0.00
2	Agricultural production ∧ livestock	342.34	0.00	1	0	0.00	0.00
10	Metal mining	30,303.31	0.00	21	0	0.00	0.00
12	Coal mining	6,954.37	0.00	6	0	0.00	0.00
14	Nonmetallic minerals, except fuels	1,654.78	0.00	3	0	0.00	0.00
17	Special trade contractors	3,392.44	0.00	7	0	0.00	0.00
21	Tobacco products	110,531.03	0.00	3	0	0.00	0.00
40	Railroad transportation	35,519.38	0.00	8	0	0.00	0.00
43	U.S. postal service	2,914.58	0.00	1	0	0.00	0.00
46	Pipelines, except natural gas	6,799.41	0.00	3	0	0.00	0.00
70	Hotels and other lodging places	32,090.29	0.00	19	0	0.00	0.00
75	Auto repair, services, and parking	2,483.67	0.00	5	0	0.00	0.00

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